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# Jellyfish as food

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**Abstract**

Jellyfish have been exploited commercially by Chinese as an important food for more than a thousand years. Semi-dried jellyfish represent a multi-million dollar seafood business in Asia. Traditional processing methods involve a multi-phase processing procedure using a mixture of salt (NaCl) and alum ($AlK[SO_4]_2 \cdot 12\ H_2O$) to reduce the water content, decrease the pH, and firm the texture. Processed jellyfish have a special crunchy and crispy texture. They are then desalted in water before preparing for consumption. Interest in utilizing *Stomolophus meleagris* L. Agassiz, cannonball jellyfish, from the U. S. as food has increased recently because of high consumer demand in Asia. Desalted ready-to-use (RTU) cannonball jellyfish consists of approximately 95% water and 4–5% protein, which provides a very low caloric value. Cannonball jellyfish collagen has shown a suppressing effect on antigen-induced arthritis in laboratory rats. With the great abundance of cannonball jellyfish in the U. S. coastal waters, turning this jellyfish into value-added products could have tremendous environmental and economicbenefits.

## Introduction

While jellyfish are shunned by swimmers in most places, several species of scyphozoan jellyfish with mild stings are edible. Edible jellyfish are largely estuarine in nature, aggregating around river mouth drainages and primarily caught from the Indian, Northwest Pacific, and Western Central Pacific Oceans by several countries including Thailand, Indonesia, Malaysia, the Philippines and China (Huang, 1988). Among the edible species *Rhopilema esculentum* Kishinouye is the most abundant and important species in the Asian jellyfish fishery which represents a multi million-dollar seafood business in Asia (Omori & Nakano, 2001). China is the first country to process jellyfish for human consumption (Morikawa, 1984). Although the Chinese have been eating jellyfish for more than a thousand years, the jellyfish industry only recently has become a commercial fishery. Other jellyfish producing countries learned the traditional processing techniques from the northern Chinese with slight modification. Processing jellyfish in Asia is a low-cost operation that requires little capital but is labor intensive.

Distributions of the jellyfish populations are sporadic and seemingly unpredictable in nature. Meterological conditions, currents, water temperature, pressure, salinity and predation may play a significant role in determining the population size (Suelo, 1986). Asian countries are actively developing fisheries management plans in an effort to conserve jellyfish. In both China and Thailand, the government fisheries departments control the jellyfish season (Rudloe, 1992). During the last several weeks of the season, the governments do not allow catching because the jellyfish are largest and are reproducing. Recently, Australia, India and the U. S. began utilizing their available species to produce jellyfish products for export. Jellyfish enters into commerce from all over the world. However, little information has been published on utilization of jellyfish for human consumption. In the present paper, the processing of edible jellyfish, the nutritional and potential medicinal value of cannonball jellyfish, and the future of jellyfish fishery in the U. S. are briefly addressed.

**Jellyfish processing**

Fresh jellyfish readily spoil at ambient temperature. Therefore, processing of jellyfish is carried out preferably within a few hours of capture while the animals are still alive. The body of jellyfish consists of a hemispherical transparent umbrella. The mouth is on the undersurface of the umbrella and is protected by fused oral arms, commonly known as 'legs'. The umbrella and oral arms of jellyfish are separated immediately after catching. Jellyfish are cleaned with sea water, scraped to remove mucus membranes and gonadal material. Both umbrella and oral arms are used in processing. Traditional methods of processing involve a step-wise reduction of the water content using salt and alum. A salt mix containing about 10% alum is used for initial salting of jellyfish using about 1 kg salt-alum mix for 8–10 kg of jellyfish (Subasinghe, 1992). Salted jellyfish are then left in the brine for 3–4 days, followed by several transfers to another container salted with fresh mix containing a smaller amount of alum. The salted jellyfish can then be heaped and left dry on a draining rack at room temperature for 2 days, and the heap is turned upside down several times during that period to allow excess water to drain out through compression by its own weight. The entire process requires 20–40 days to produce a salted final product with 60–70% moisture and 16–25% salt (Huang, 1988; Subasinghe, 1992). The processed jellyfish has a yield of about 7–10% of the raw weight depending on the species and processing formula.

Preservation of jellyfish in a mixture of salt and alum is necessary to obtain products of desirable structure and texture. Alum reduces pH, acts as a disinfectant and a hardening agent, giving and maintaining a firm texture by precipitating protein (Huang, 1988). Salt aids in reducing the water content and in keeping the product microbially stable. Salt or alum used singularly in the processing of jellyfish does not produce a product of satisfactory properties (Wootton et al., 1982). Extensive liquidation of the tissue occurs in the absence of salt, while disagreeable odors develop in the absence of alum. In Malaysia and Thailand, a small amount of soda is often added in addition to salt and alum. Addition of soda facilitates water dehydration in the curing solution and increases the crispiness of the cured jellyfish. In China, soda is omitted. Because there are large variations among species, and even with different batches of the same types of jellyfish, processors vary the amounts of alum and soda in the salt from one batch to the next to achieve standardization of product. Processing jellyfish is more of an art than an exact science, hence Asians employ Jellyfish Masters who make adjustments in the amount of salt, alum, soaking periods and compression to obtain the right quality of product (Rudloe, 1992). Exact procedures are often kept as trade secrets. Processing reduces the pH from about 6.6 in fresh cannoball jellyfish to 4.5–4.8 (Table 1). The lowered pH greatly reduces the possibility of microbial growth and enhances the shelf life of the product. The quality of salt affects the ash content in processed jellyfish. Low grade curing chemicals and processing equipment can be the source of heavy metal contamination (Hsieh et al., 1996). Refined curing agents should be used for jellyfish processing.

Cured jellyfish has a special crunchy and crispy texture that makes it unique. The price also depends on the quality of the processed jellyfish as measured by its texture, a combination of tender, elastic and crunchy characteristics, and its colour. The colour of freshly processed jellyfish is creamy white, but gradually turns yellowish as the product ages. In the Asian jellyfish market, a whiter coloured product has higher retail value. Yellow, but not a brown colour, is acceptable. The longer the sample remains around, the darker it becomes. If it remains too long, it turns brown and the product is unacceptable.

The salted jellyfish has a stable shelf life up to 1 year at room temperature. The shelf life can be increased to more than 2 years if the product is kept cool, however, freezing spoils the product, which dries out completely and becomes covered with wrinkles. Prolonged storage at warm ambient temperature may cause a loss of crispness or spoilage of the product. The market price varies considerably depending on the size and condition. The larger the jellyfish, the better is the price. Oral arms product has a lower market value than umbrella due to the irregular shape. A premium Grade A jellyfish, with a wholesale price of $10.00–12.00 per pound in Asia, must be 18 inches in diameter, have a white to creamy colour, and have a crispy texture and be tender at the same time.

*Table 1.* Chemical composition, caloric value, and pH of fresh cannonball jellyfish, *Stomolophus meleagris*, desalted ready-to-use (RTU) processed cannonball products, and a RTU commercial Malaysian *Rhopilema* product. Numbers are means ($\pm$ one standard deviation) of 3 determinations from composite samples

| Composition | Fresh cannonball umbrella | RTU Malaysian umbrella | RTU cannonball umbrella | RTU cannonball leg |
|---|---|---|---|---|
| Moisture (%) | 96.10 (0.06) | 95.63 (0.01) | 95.04 (0.04) | 94.08 (0.02) |
| Ash (%) | 1.25 (0.16) | 0.69 (0.00) | 0.33 (0.00) | 0.34 (0.01) |
| Protein (%) | 2.92 (0.04) | 4.13 (0.01) | 4.69 (0.03) | 5.60 (0.02) |
| Fat (%) | $< 0.01$ | $< 0.01$ | $< 0.01$ | $< 0.01$ |
| Total (%) | 100.27 | 100.45 | 100.06 | 100.02 |
| Cal 100 $g^{-1}$ | 11.68 | 16.52 | 17.84 | 22.4 |
| PH | 6.67 (0.01) | 4.64 (0.01) | 4.46 (0.01) | 4.46 (0.01) |

**Preparation of jellyfish dishes**

Jellyfish is more than a gourmet delicacy; it is a tradition. A Chinese wedding or formal banquet is rarely completed without a jellyfish salad. The processed jellyfish should be desalted and rehydrated in water for several hours to overnight before preparing the jellyfish dishes. The desalted ready-to-use (RTU) products have little flavour but are served with sauces or as part of more elaborate dishes. The Chinese have various methods for preparing jellyfish, cooked or uncooked. They usually are shredded, scalded and served in a dressing composed of oil, soy sauce, vinegar and sugar. Sliced jellyfish may be eaten as a salad mixed with shredded vegetables and/or thinly sliced meat. Japanese prepare cured jellyfish by rinsing in fresh water, cutting into thin strips and served with vinegar as an appetizer (Firth, 1969). In Thailand, cured jellyfish are sliced into small threads like noodles, washed several times to remove salt and dipped in hot water; the dipped jellyfish is ready for use in various recipes (Soonthonvipat, 1976).

The overnight desalting procedure and preparation of jellyfish dish may become a barrier for modern consumers with busy life styles. This has been overcome by developing shredded RTU products with varieties of flavor and sauces. Recently, shredded jellyfish have appeared on the Japanese market packaged together with condiments such as wasabi or mustard as a convenient ready-to-eat food. The preparation of shredded RTU products will also eliminates the problems related to the size of the jellyfish and increase the utilization of their oral arms.

**Nutrient composition**

Not only are they delectable, but jellyfish are a natural diet food. We have analyzed the chemical composition of RTU cannonball jellyfish products and compared with that of a commercial Malaysian *Rhopilema* product and a fresh cannonball jellyfish sample. Results of the chemical composition, pH and calculated caloric value per 100 g of serving are shown in Table 1. RTU jellyfish mainly consists of water and protein. They are low in calories, with no detectable crude fat and cholesterol, and trace amounts of sugar. The average moisture content of RTU samples is in a range of 94.1–95.6% . The tissue can bind a large quantity of water; yet maintain a non-watery, crunchy texture.

Fresh unprocessed jellyfish are rich in minerals such as Na, Ca, K and Mg, but the processed product is depleted of salts after desalting in fresh water (Hsieh et al., 1996). Salt (NaCl) can be completely removed by soaking in clean water. The hardness of water used and the number of water changes during desalting could affect the residual amount of these elements. However, RTU jellyfish contain a significantly higher amount of aluminum than fresh jellyfish (Hsieh et al., 1996). Apparently, aluminum is contributed from the curing agent, alum and remains in the tissues in a bound form. Processing time, temperature and the amount of alum used affect the retention of aluminum in jellyfish tissues (unpublished data).

Except in relatively well-developed gonads during the reproductive cycle, jellyfish contain no visible lipid deposits (Joseph, 1979). Hooper & Ackman (1973) report that the lipid content of whole jellyfish range from 0.0046 to 0.2% on a wet weight basis. In our study, crude fat content in RTU cannonball jellyfish is less than 0.01%. This may be due to the complete removal of mucus and gonads, which contain trace amounts of lipids. According to Hsieh & Rudloe (1994), the cholesterol content of whole fresh jellyfish calculated on a wet weight basis is less than 0.35 mg 100 $g^{-1}$ based on four species of jellyfish, thus, jellyfish can be declared as a fat-free and cholesterol-free food.

Carbohydrate is the other macronutrient that contributes to the caloric value of food. In jellyfish tissue, a trace amount of carbohydrate in the form of sugar is bound to protein as glycoproteins (Kimura et al., 1983). The sum of the percentages of water, lipid, protein, and ash is approximately 100%; therefore, the carbohydrate content in jellyfish is negligible for calorie calculations (Table 1). The calculated caloric value for a normal serving (100 g) of RTU is less than 20 Kcal. Such low caloric value makes jellyfish a natural diet food from the sea.

Protein analysis of salted jellyfish indicate that a Malaysian commercial product and a Chinese product contain an average of 5.5 and 6.8 g of protein per 100 g of salted product, respectively (Huang, 1988). However, the salted product is not the form for consumption. Our results show that percent crude proteins in RTU cannonball jellyfish ranged from 4.7% in umbrellas to 5.6% in legs, values that are higher than the RTU Malaysian commercial product (Table 1). When the combined moisture and ash content increases, protein content decreases. Amino acid analysis shows that tryptophan, a limiting amino acid, is either not detectable or is found in small amounts in jellyfish tissue (Kimura et al., 1983). Thus, the nutritional quality of jellyfish protein quality is low. Glycine accounts for one third of the total amino acid residues with a high proportion of hydroxyproline and hydroxylysine indicating that jellyfish protein is mainly collagen (Barzansky et al., 1975).

## Medicinal value of jellyfish

Jellyfish have long been recognized for medicinal value (Omori, 1981; Hsieh & Rudloe, 1994). It is believed to be an effective cure for arthritis, hypertension, back pain and ulcers, while softening skin and improving digestion. Jellyfish is also alleged to remedy fatigue and exhaustion, stimulate blood flow during the menstrual cycle of women, and ease any type of swelling. Most of these claims regarding the medicinal value of jellyfish are described in non-scientific publications in Chinese. In Korea, jellyfish are promoted on television and in women?s magazines as an aid for weight loss and beautiful skin. Australian aboriginal shamans have prescribed dried jellyfish powder as a treatment for burns (Hsieh & Rudloe, 1994). However, no scientific research has been carried out to document the medicinal efficacy of jellyfish. Collagen has been hypothesized to be the ingredient in jellyfish contributing to the beneficial health effects because collagen is the essential building material of muscle tissue, cartilage and bone, and has a great medicinal promise (Hsieh & Rudloe, 1994).

Recently, we conducted a small scale animal study investigating the health effect of jellyfish collagen on arthritis in rats. Laboratory rats were divided equally into 5 experimental groups with 5 animals in each group. Three groups were fed daily with 10 $\mu$g of jellyfish collagen per rat for 6 days before (pre-JC), after (post-JC), and before and after (pre & post-JC) injection of the arthritis inducing reagent, bovine type II collagen (Wood et al., 1969). A positive control group was induced with arthritis without collagen treatment and a negative control group consisted of normal healthy rats. All animals were examined daily for joint thickness and swelling to evaluate the onset and severity of the disease. An arthritis score was derived by grading the severity of involvement of each paw from 0 to 4 (0=normal, 1=redness, 2=redness plus mild swelling. 3=severe swelling, 4=joint deformity) according to Trentham et al. (1977). Delayed-type hypersensitivity and serum anti-CII antibody levels were also monitored according to Yoshino et al. (1995). The average onset of arthritis in the positive control group was 19 days after induction of the disease, while in the jellyfish-fed groups was delayed to 24–29 days. The average arthritis scores for all jellyfish fed groups were lower than the positive control group. Our results demonstrated that laboratory rats fed with low doses of jellyfish collagen had significantly ($p < 0.05$) reduced incidence, onset and severity of antigen-induced arthritis, a model that shares clinical, histological, immunological and genetic features with human rheumatoid arthritis. Detailed methods and complete results of the study will be published elsewhere.

## Cannonball jellyfish - A new fishery in the United States

*Stomolophus meleagris* or ‘cannonball jellyfish’ is an edible rhizostome jellyfish species. Cannonball jellyfish are small in size; about 127 mm high and 180 mm wide. They are hemispherical, thick, tough and milky-bluish or yellowish in colour, with or without a pale-spotted brown band around the margin. Cannonball jellyfish have no tentacles. Rather, they have 16 short, forked fused oral arms. Jellyfish of this species are of no significant public hazard because the toxin of their stinging cells (nematocysts) is relatively innocuous to humans (Toom & Chan, 1972).

Cannonball jellyfish are frequently seen in coastal waters from North Carolina to Florida and in the northern Gulf of Mexico (Mayer, 1910). Each year, from August to December, ranging from Chesapeake Bay to Texas, millions of cannonball jellyfish can be observed. When abundant, they become a nuisance to shrimp fishermen by clogging the nets and crushing the shrimp. They sometimes severely damage fishing nets due to their huge volumes and weights (Huang, 1988). One swarm observed at Port Arkansas, Texas, was estimated drifting through the channel at a rate of 2 million per hour (Meinkoth, 1981). Kraeuter & Setzler (1975) reported finding jellyfish of this species from March through October off the coast of Georgia. Burke (1976) noted that *S. meleagris* was almost always present in the Mississippi Sound. In South Carolina, they occur throughout the year in abundance (Calder & Hester, 1978). It has also been recorded from southern California to Ecuador in Pacific and from the Sea of Japan to the South China Sea in the western Pacific (Kramp, 1961; Omori, 1978). The species has also been reported from New England to Brazil in the western Atlantic Ocean (Kramp, 1961; Larson, 1976).

Because cannonball jellyfish are so abundant in the coastal waters of the U.S., they have been considered a nuisance. Turning cannonball jellyfish into value-added products has tremendous environmental and economic benefits. Interest in utilizing cannonball jellyfish from the U. S. has increased recently because of high consumer demand in Asia. A fishery in Florida has initiated the first venture of processing cannonball jellyfish since 1992 (Rudloe, 1992). They use the Asian method to clean and cure the jellyfish. Since cannonball jellyfish are much smaller than the Asian species, reduced-time processing methods were developed to produce the salted product (Huang, 1988; Hsieh et al., 1996).

A sensory study was conducted at Auburn University to compare the colour, texture and overall preference of laboratory processed cannonball umbrella and leg products with a commercial Malaysian product (Leong, 1995). The study involved 51 panelists including 35 who had consumed jellyfish at least once before, and 16 inexperienced panelists. The three jellyfish samples were desalted overnight, sliced, coded with 3-digit random numbers and presented to the panalists on a white plate at the ambient temperature. An eight-point structured hedonic scale was used to evaluated the lightness of colour, crunchiness and preference of the these unflavoured jellyfish products. Based on the sensory scores, cannonball products that had been stored in a refrigerator for 1 year presented a whiter colour and crunchier texture than the commercial one tested (Table 2). Significant differences ($p \leq 0.05$) were found between the cannonball products and the Malaysian sample on the attribute of colour. Both cannonball products were rated lighter in colour than the commercial product. It is possible that the cannonball products were more recently processed than the commercial product. The low temperature of refrigerated storage also keeps the light colour longer. In terms of texture and overall preference, experienced panelists rated cannonball umbrella as a crunchier product than the Malaysian sample and gave higher score of preference to the cannonball products. Results from inexperienced panelists showed no significant difference in crunchiness and overall preference among all samples tested. Leg tissue was accepted as well as the umbrella parts of the cannonball jellyfish.

*Table 2.* Sensory evaluation of jellyfish products from 35 experienced panelists who had consumed jellyfish before, and 16 inexperienced panelists who had not consumed jellyfish before. A structured 8-point hedonnic scale was used to evaluate the lightness of colour, crunchiness of the texture and overall preference of unflavoured jellyfish product. The higher the score indicates the lighter in colour, crunchier in texture, and more preferred product. Means within rows followed by the same letter are not significantly different at $p < 0.05$

| Sample | Malaysian umbrella | Cannonball umbrella | Cannonball leg |
|---|---|---|---|
| Experienced panelists | | | |
| Colour, lightness | $2.80^b$ | $5.31^a$ | $5.74^a$ |
| Crunchiness | $4.97^b$ | $7.03^a$ | $5.63^b$ |
| Overall preference | $5.06^b$ | $5.80^a$ | $4.97^b$ |
| Inexperienced panelists | | | |
| Colour, lightness | $3.00^b$ | $5.19^a$ | $5.56^a$ |
| Crunchiness | $6.25^a$ | $6.44^a$ | $5.75^a$ |
| Overall preference | $4.88^a$ | $4.88^a$ | $4.06^a$ |

Processed jellyfish are in high demand in Asia (Omori & Nakano, 2001). For example, Japan is one of the leading jellyfish consuming countries. More than 10 000 tons of raw jellyfish are caught in 1978 and 1979 in the Ariake Bay; however, domestic production is too small to meet the high consumer demand. In 1980, Japanese imports from countries like Malaysia, China, Indonesia, Burma and the Philippines amounted to more than $40 million (Omori, 1981). On the other hand, jellyfish populations have been unstable or declining in Asian waters due to pollution, over fishing or changing climate (personal comunication), causing Asian dealers to explore new sources of jellyfish. Although the U. S. cannonball jellyfish industry is in its infancy, its future looks promising due to the abundance of these jellyfish in U. S. waters, and the increasing Asian demand. The utilization of this valuable marine resource will potentially reduce the interference of this species with other fisheries and tourists and offer a great economical opportunity for the deprived fishing industry along the Gulf of Mexico (Rudloe, 1992). In the long run, jellyfish may be a valuable health food and collagen source for a world clientele. Greater recognition of the value of jellyfish will enable the U. S. to develop the jellyfish industry for penetration into the world market.

## Future product developments

In spite of their wide commercial availability, jellyfish processing and utilization are not sufficiently studied and reported in the literature. Intensive labor harvesting and traditional manual processing are still used in Malaysia, China, Indonesia and elsewhere. With the trend towards globalization of the jellyfish industry, a cost-effective harvesting design and automated processing are needed to reduce the labor cost and improve production. The establishment of a standardized production for optimum quality from each species will facilitate the quality control of the jellyfish product.

Even though cured jellyfish is a delicacy with high demand in Asia, Westerners are repulsed by the idea of eating them. The jellyfish product is a great seafood alternative that can be sprinkled on salads for extra crunch, prepared as seafood salad, or displayed on the sushi bar. This low calorie seafood product with the potential of being used for treating rheumatoid arthritis or providing other health benefits, could eventually become welcome by Westerners.

The myths of the medicinal value of eating jellyfish should be unveiled by conducting carefully-controlled studies on animal models and human subjects. The preventive and/or therapeutic effects of jellyfish collagen on arthritis needs to be confirmed, and the effective dose range, treatment duration and mechanisms of the suppressing effect should be further investigated in animal models. Carefully controlled preclinical studies would be essential before use of jellyfish collagen as a treatment for rheumatoid arthritis patients. Because jellyfish are a huge untapped resource of collagen, they may find a special niche in the near future for food, clinical and industrial applications.

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